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(54) **Holographic diffraction grating patterns and methods for creating the same**

Holographische Beugungsgitterstrukturen und Herstellungsverfahren

Structures de réseaux de diffraction holographiques et méthode de fabrication

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The file contains technical information submitted after the application was filed and not included in this specification

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to the field of holography, and more particularly to a method for creating two-dimensional holographic patterns.

2. Prior Art.

Holographic images have been a source of wonder and amusement for a number of years. Holographic images create the impression of a three-dimensional object from the illumination of a two-dimensional hologram. Holographic images have also been used for various practical applications wherein their unique characteristics readily distinguish the same from conventional images. In that regard, probably the best known example at the present time is the holographic image of a dove used on credit cards for authentication purposes. In particular, the advantage of using a hologram to provide a readily recognizable holographic image is that the same is not reproducible by ordinary printing or photographic processes. The difficulty with such holograms, however, is that they are relatively expensive to first produce, and not particularly inexpensive to reproduce in quantity, thereby tending to limit their application for authenticating items to those things of sufficient value to justify the costs involved. In comparison, there are a large number of items of lesser value which, without some similar authenticating marking, are frequently counterfeited and used, to the very substantial loss of the issuer. Such things include tickets and passes of all kinds, including tickets for sporting events, passes for public transportation, etc. In the cases of these examples, the counterfeit copies are offered to a relatively unsophisticated ticket taker or bus driver under circumstances not allowing significant time and attention to evaluate the same, so that the quality of the counterfeit copy need not be that good to have a high likelihood of being accepted. While the addition of color to tickets in past years has helped, the increased popularity of color copiers has more recently offset that gain. If, on the other hand, like the credit card, such items could be authenticated by an appropriate hologram at a reasonable cost, the genuine item would be quickly recognizable by the casual observer, and would be too costly and difficult to reproduce in small quantity for counterfeiting purposes. Further, if the hologram could be changed frequently, such as by way of example changed for each sporting event, or changed monthly for a one month transportation pass, authentication becomes even easier at the time of use of the ticket, pass, etc., and more difficult for the would be counterfeiter to reproduce.

BRIEF SUMMARY OF THE INVENTION

Decorative holographic diffraction grating patterns and methods of creating the same which provide low cost computer generation of two-dimensional holographic patterns and the generation of very large holographic patterns. In accordance with the method, the desired pattern is made up of a large plurality of individual spots, each spot comprising a holographic diffraction grating of a predetermined grating spacing and angular orientation for that spot. Variation of the angular orientation and/or grating spacing between spots and/or groups of spots provide the desired holographic effect. The spot locations may vary as desired, including locations drawing out a desired pattern, and two-dimensional orthogonal matrices in which a pattern is drawn by variations between spots or group of spots as in a raster scan type image. Various embodiments and methods for creating the same are disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic representation of one type of holographic pattern which may be formed by the present invention.

Figure 2 is a view taken on an expanded scale illustrating the use of rectangular or square spots in the holograms of the present invention.

Figure 3 is a block diagram of one embodiment of apparatus for forming the holograms of the present invention.

Figure 4 is a block diagram of an embodiment of the apparatus for forming the hologram of the present invention similar to the apparatus of Figure 3 but further incorporating the ability to vary the spacing of the diffraction grating as well as the angle thereof.

Figure 5 is a schematic illustration of the apparatus of Figure 4 for varying the diffraction grating spacing.

DETAILED DESCRIPTION OF THE INVENTION

First referring to Figure 1, a schematic representation of a hologram fabricated in accordance with the present invention may be seen. The pattern illustrated in the Figure is a relatively nongeometric pattern, though is defined by a relatively large plurality of individual spots, each of which is a diffraction grating of a predetermined grating separation and angle with respect to the orthogonal axes of the spot matrix. As illustrated in the Figure, each spot in the entire matrix in this example is comprised of a diffraction grating, with the result that different patterns and characteristics of the hologram will be viewable from different angles when the same is illuminated, typically with white light. Each spot of course will also have a characteristic color which will vary depending upon the angle of the incident illumination and the observer. Obviously, of course, if desired, only specific spots or spot patterns might consist of diffraction grat-

ings, with other areas merely being one or more solid colors or some other form, so that when the same is observed from appropriate angles the design but not the background will appear to have holographic characteristics. Further, of course, if desired, a free form pattern of spots, each of appropriate diffraction grating angle and spacing, may be used rather than the orthogonal spot matrix illustrated, though in general the orthogonal matrix is preferred as being more consistent with computer generation techniques and more readily reproducible by a modified step and repeat process.

In Figure 1, each spot comprises a single circular diffraction grating of parallel, equally spaced grating lines. This is not a limitation of the present invention, however, as spots of other physical geometries, such as, by way of example, square or rectangular geometries as illustrated in Figure 2 may be used. Here the spots, in essence, totally fill the area involved. The spots as shown are being shown for illustration purposes only and comprise no specific pattern. Also illustrated in Figure 2, however, are regions 20 and 22, both of which comprise, in essence, an overlay of two diffraction patterns so as to make the spot, when illuminated, visually active from additional angles and/or with other colors. In that regard, while regions 20 and 22 comprise an overlay of diffraction gratings of the same line spacings but with different angles, overlays with the same angle, but different grating spacing and/or with different angles and different spacings of course are readily useable, depending upon the visual effects desired.

Also, if desired, diffraction gratings comprising curved lines to spread the viewing angle of each spot, such as shown in region 24, may also be used within the principles and concepts of the present invention. However, spot sizes normally will be kept sufficiently small so that the effect achievable by overlaying diffraction grating patterns may be substantially achieved by merely placing the two desired patterns side by side in neighboring spot positions, so that in many cases overlaying of patterns will not be necessary. Also, as shall subsequently be seen, certain methods of forming the diffraction grating patterns of the present invention will readily accommodate the use of overlaying patterns of different spacing and/or angles at the same spot location, though other techniques do not lend themselves well to such overlays. Similarly, the extent of curvature one might normally prefer to have within a given spot size usually will effectively be more easily accomplished by using smaller spot sizes and changing the diffraction grating angle between adjacent spots. In any event, it may be appreciated that by using specific spot patterns, a certain pattern may be visible under certain lighting and viewing angle conditions (varying in color as lighting and/or viewing angles change), with another pattern or additional patterns being viewable under other angles of lighting and viewing). Thus, by way of example, for authentication purposes a hologram in accordance with the present invention might be placed on each football game ticket showing from certain angles the date of the game and from other angles the logo of one or both teams, all in a characteristic multi and varying color pattern so as to not be susceptible to unauthorized duplication.

Now referring to Figure 3, a block diagram of a system for forming a hologram in accordance with the present invention may be seen. As shown therein, a laser 26 directs coherent light to a rotatable head 28 having a diffraction grating mounted therein. The diffraction grating, aside from passing part of the primary or zero order beam 30, diffracts the incoming beam to create the upper and lower first order beams 32 and 34. Beam 30 is blocked by a suitable mask, with beams 32 and 34 being focused to a common point by lens 36 which may be either a glass or a holographic lens. For best performance, the lens should have a small F number, such as, by way of example, in the range of 0.8 to 1.5 so that the two first order beams striking the photosensitive plate 38 are at a sufficient angle to produce a grating with the desired spacing. The photosensitive plate 38 itself is mounted on a motorized X-Y table 40 with the bounds of each spot to be exposed being defined and limited by an aperture plate 42 which may define a round, square, or other shaped spot as desired. Finally, an electronic shutter 44 is provided in the optical path to control the exposure time and, of course, prevent exposure when incrementing the system for the next exposure.

In operation, a computer 46 controls electronic shutter 44 and a three channel servo motor controller 48 to control motor 52 which rotates the diffraction grating 28, and to control the two axis table 40 to successively increment the position of the photosensitive plate 38 from spot location to spot location. In the system shown in the Figure, the angular orientation of the diffraction grating for a spot may be controlled by rotating the head 28 under control of the computer and, of course, exposing the photosensitive plate at a given spot location, with different angle settings of rotating head 28 providing diffraction grating patterns, such as, by way of example, those shown as patterns 20 and 22 in Figure 2. The system of Figure 3 will not, however, conveniently allow the variation of the separation of the lines in the diffraction grating, something that can readily be achieved in embodiments hereinafter described.

In operation, computer 46 is used to create the desired pattern, preferably in color on the display 50, each different color representing a different diffraction grating and/or grating angle in accordance with a predetermined relationship or mapping therebetween. Once the desired pattern is created, the print, or expose, operation is initiated. The computer then controls the two axis table 40 to present the first spot position for exposure, rotates head 28 to the desired diffraction grating angle and opens and closes shutter 44 for the exposure of the respective spot. The desired efficiency or brightness of each spot can be controlled by the length of the exposure. If a second grid is to be overlayed on the first, motor 52 is controlled to rotate head 28 to the next desired po-

sition and shutter 44 again opened and closed appropriately. Once a given spot has been exposed as desired (typically with a single exposure), table 40 is advanced to the next position, head 28 rotated to the desired angular position for that next spot and shutter 44 again opened and closed appropriately so as to expose the respective spot on the photosensitive plate 38. Obviously, the process may be continued under full control of the computer until the exposure of the photosensitive plate 38 or at least a pattern thereon is complete. Thereafter, the same may be developed and reproduced using, by way of example, any of the commonly used techniques for reproducing holograms in general, including contact printing processes, as well as roller and other embossing processes, hot stamping and the like.

Obviously, from the foregoing it may be seen that the computer control of the system based upon image information first created on the computer will allow the rapid creation and/or alteration of a design without requiring the production of the corresponding three-dimensional object or alternatively the creation of two-dimensional art work by hand. By way of example, the creation of a hologram which will provide the date as one image and a name identifying the event as another image for authentication of tickets to the event could be generated on the computer screen exceedingly fast, and then automatically converted to an actual exposed and developed hologram for subsequent reproduction very efficiently.

Now referring to Figure 4, an embodiment similar to that of Figure 3 may be seen, the embodiment of Figure 4 further including the capability of varying the grating spacing as well as the grating angle. In this embodiment, components which may be substantially identical to those of Figure 3 and function in the same general manner are identified with the same numerals. However, in this embodiment, instead of a single motor 52 controlled to rotate diffraction grating 28 to the desired angle, two motors 52a and 52b are provided, each controllably rotating members 28a and 28b comprising a variable diffraction grating assembly as shown in Figure 5. Here a rotating head 140 carries a number of diffraction gratings 142, 144, etc. disposed in a circle therearound, which circle passes through the center or axis of members 28a and 28b. The diffraction grating member 140, eight being shown in the figure, are each of a different grating spacing, for simplicity each being angularly oriented so that rotation of member 140 in angular increments of 45 degrees and multiples thereof will bring a new diffraction grating onto the axis of the assembly, though each with the same angular orientation when so disposed. Schematically illustrated in the figure is a gear 146 driving the periphery of member 140, with a larger gear 148 driven by member 28b (Figure 4) being connected to and driving gear 146. By proper selection of the gear ratios, a single rotation of member 28b by motor 52b will rotate the diffraction grating member 140 also through a single rotation. A rotation of member 28a by motor 52a, on the other hand, will rotate a member supporting the axes of members 140 and gears 146 and 148. Thus, the rotation of members 28a and 28b in unison will rotate the entire assembly about the optical axis, thereby rotating the diffraction grating which is aligned with the optical axis to any desired angle (Preferably in relatively small increments of, say, 1 degree and multiples thereof). On the other hand, rotation of member 28b in 45 degree increments and multiples thereof without rotation of member 28a will vary the diffraction grating aligned with the optical axis of the system, but not the angle thereof. Thus in the example shown and described, any of eight diffraction gratings may be aligned with the optical axis of the system, with all of them when so aligned being rotatable about the optical axis in relatively small angular increments, such as 1 degree. Obviously, of course, if desired various other schemes might be employed for varying the diffraction grating spacing, such as, by way of example, a drive motor may be provided on the rotatable head for rotating member 140, though such a scheme would require slip rings or some other means of providing power to the rotating assembly. In other cases, however, where only a small number of diffraction grating spacings are desired, such as, by way of example, if only two different spacings are desired, the diffraction grating might slide onto and away from the optical axis of the system under the influence of gravity, this being particularly facilitated by the fact that the diffraction grating angles repeat every 180 degrees rather than every 360 degrees, allowing one grating to be in place over a 180 degree range of head rotation to provide the full grating rotation capability, and the other grating to be in position over the other 180 degree head rotation to provide the full grating angle range for the second grating.

There has been described herein new and unique holographic diffraction grating patterns and methods for creating the same which have many advantages over conventional hologram creation and reproduction techniques. While the holograms of the present invention have been referred to shown and described herein in various places as being orthogonal spot matrices, it is to be understood that the same are not limited to the use of orthogonal matrices or the use of spots defining a pattern which fall on matrix locations of an orthogonal matrix (though such is preferred) but instead may be used to form free-form patterns or even to form spots localized but distinctive and readily recognizable spots of glitter in images of any kind formed by other techniques, such as, by way of example, ordinary printing procedures.

Claims

1. A method of forming holographic diffraction grating patterns, the method comprising the steps of:

   (a) providing a member (38) having a photosensitive region thereon;

(b) generating a pair of light beams (32,34);
(c) directing said light beams (32,34) onto a spot on said photosensitive region of said member (38) such that a holographic diffraction grating is created within said spot of said photosensitive region, said spot having an area of only a very small fraction of the area of the photosensitive region; and
(d) repeating step (c) a plurality of times for a plurality of spots having different locations on said photosensitive region to define a pattern thereon;

the method being characterised in that said pair of light beams (32,34) are generated with a diffraction grating (28) and directed onto said spot by a lens (36).

2. A method as claimed in claim 1, characterised by the step of selecting the relative orientations of said diffraction grating (28) and said member (38) having a photosensitive region thereon, such that at least some said spots are formed with holographic diffraction gratings containing lines which extend in different directions.

3. A method as claimed in claim 1 or 2, characterised in that different diffraction gratings (140,142,146...), having different grating spacings, are used to generate said pair of light beams (32,34) for at least some of said spots.

4. A method as claimed in any preceding claim, characterised in that said holographic diffraction gratings are created, in steps (c) and (d), in a manner so as to tract out a specific decorative pattern.

5. A method as claimed in any preceding claim, characterised in that the holographic diffraction gratings are created, in steps (c) and (d), in a raster scan pattern.

6. A method as claimed in any preceding claim, characterised in that said spots are round.

7. A method as claimed in any one of claims 1 to 5, characterised in that said spots are polygonal.

8. A method as claimed in any preceding claim, characterised in that the length of exposure of each spot by said beams (32,34), in steps (c) and (d), is varied for at least some of said spots.

Patentansprüche

1. Verfahren zum Bilden holographischer Beugungsgitterstrukturen mit den Schritten:

a) zur Verfügungstellen eines Elements (38) mit einem darauf angeordneten fotosensitiven Bereich;
b) Erzeugen eines Paars von Lichtstrahlen (32, 34);
c) Richten dieser Lichtstrahlen (32, 34) auf einen Fleck auf diesem fotosensitiven Bereich dieses Elements (38) dergestalt, daß innerhalb dieses Flecks des fotosensitiven Bereichs ein holographisches Beugungsgitter geschaffen wird, wobei die Fläche dieses Flecks nur einen sehr kleinen Bruchteil der Fläche des fotosensitiven Bereichs ausmacht;
d) mehrfaches Wiederholen des Schrittes c) für eine Mehrzahl von an verschiedenen Stellen des fotosensitiven Bereichs angeordneten Flecken, um auf dem fotosensitiven Bereich eine Struktur zu bilden;

wobei das Verfahren dadurch gekennzeichnet ist, daß das Paar von Lichtstrahlen (32, 34) mit einem Beugungsgitter (28) erzeugt und mittels einer Linse (36) auf diesen Fleck gerichtet wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die relative Orientierung des Beugungsgitters (28) und des Elements (38) mit einem darauf angeordneten fotosensitiven Bereich dergestalt gewählt wird, daß wenigstens einige der Flecken mit holographischen Beugungsgittern gebildet werden, die Linien enthalten, die sich in unterschiedliche Richtungen erstrecken.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß unterschiedliche Beugungsgitter (140, 142, 146...) mit unterschiedlichen Gitterabständen verwendet werden, um dieses Paar von Lichtstrahlen (32, 34) für wenigstens einige dieser Flecken zu erzeugen.

4. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die holographischen Beugungsgitter in den Schritten c) und d) in einer Weise gebildet werden, daß eine spezifische dekorative Struktur entsteht.

5. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die holographischen Beugungsgitter in den Schritten c) und d) in einem Rasterablenkmuster gebildet werden.

6. Verfahren nach einem der vorgehenden Ansprüche, dadurch gekennzeichnet, daß die Flecken rund sind.

7. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Flecken polygonal sind.

8. Verfahren nach einem der vorgehenden Ansprüche, dadurch gekennzeichnet, daß die Dauer der Belichtung eines jeden Flecks durch die Strahlen (32, 34) in den Schritten c) und d) für wenigstens einige der Flecken variiert wird.

Revendications

1. Procédé de formation de structures de réseaux de diffraction holographiques, le procédé comprenant les étapes consistant à :

   (a) prévoir un élément (38) présentant une zone photosensible ;
   (b) générer une paire de faisceaux lumineux (32, 34) ;
   (c) diriger lesdits faisceaux lumineux (32, 34) sur un point de ladite zone photosensible dudit élément (38), de façon à créer un réseau de diffraction holographique dans ledit point de ladite zone photosensible, ledit point ayant une surface qui ne représente qu'une très petite fraction de la surface de la zone photosensible ; et
   (d) répéter l'étape (c) plusieurs fois pour plusieurs points à des emplacements différents de ladite zone photosensible, afin de définir une structure sur celle-ci ;

   le procédé étant caractérisé en ce que ladite paire de faisceaux lumineux (32, 34) est générée au moyen d'un réseau de diffraction (28) et dirigée sur ledit point au moyen d'une lentille (36).

2. Procédé selon la revendication 1, caractérisé par l'étape consistant à choisir les orientations relatives dudit réseau de diffraction (28) et dudit élément (38) présentant une zone photosensible, de façon à former au moins certains desdits points en réseaux de diffraction holographiques comprenant des lignes qui s'étendent dans des directions différentes.

3. Procédé selon la revendication 1 ou 2, caractérisé en ce que différents réseaux de diffraction (140, 142, 146...), présentant des espacements dc diffraction différents, sont utilisés afin de générer ladite paire de rayons lumineux (32, 34) pour au moins certains desdits points.

4. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que lesdits réseaux de diffraction holographiques sont formés, aux étapes (c) et (d), de façon à faire apparaître une structure décorative particulière.

5. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que les réseaux de diffraction holographiques sont formés, aux étapes (c) et (d), selon une structure de balayage tramé.

6. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que lesdits points sont ronds.

7. Procédé selon l'une quelconque des revendications 1 à 5, caractérisé en ce que lesdits points sont polygonaux.

8. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que la durée d'exposition de chaque point sous lesdits faisceaux (32, 34), aux étapes (c) et (d), est modifiée pour au moins certains desdits points.

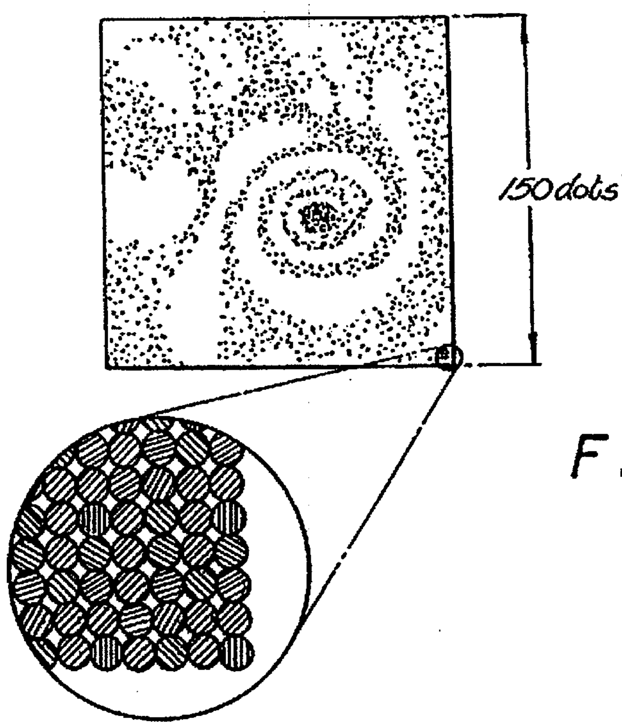

FIG. 1

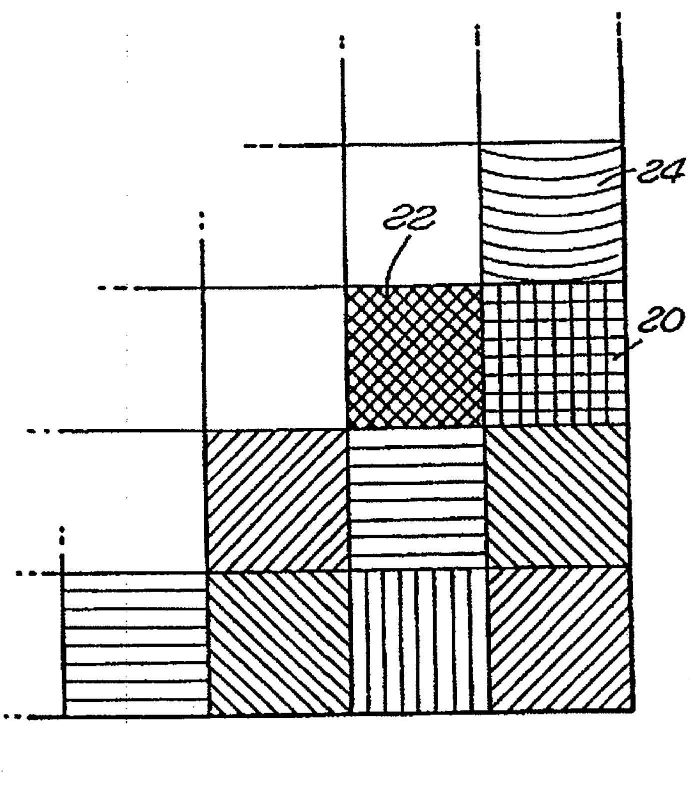

FIG. 2

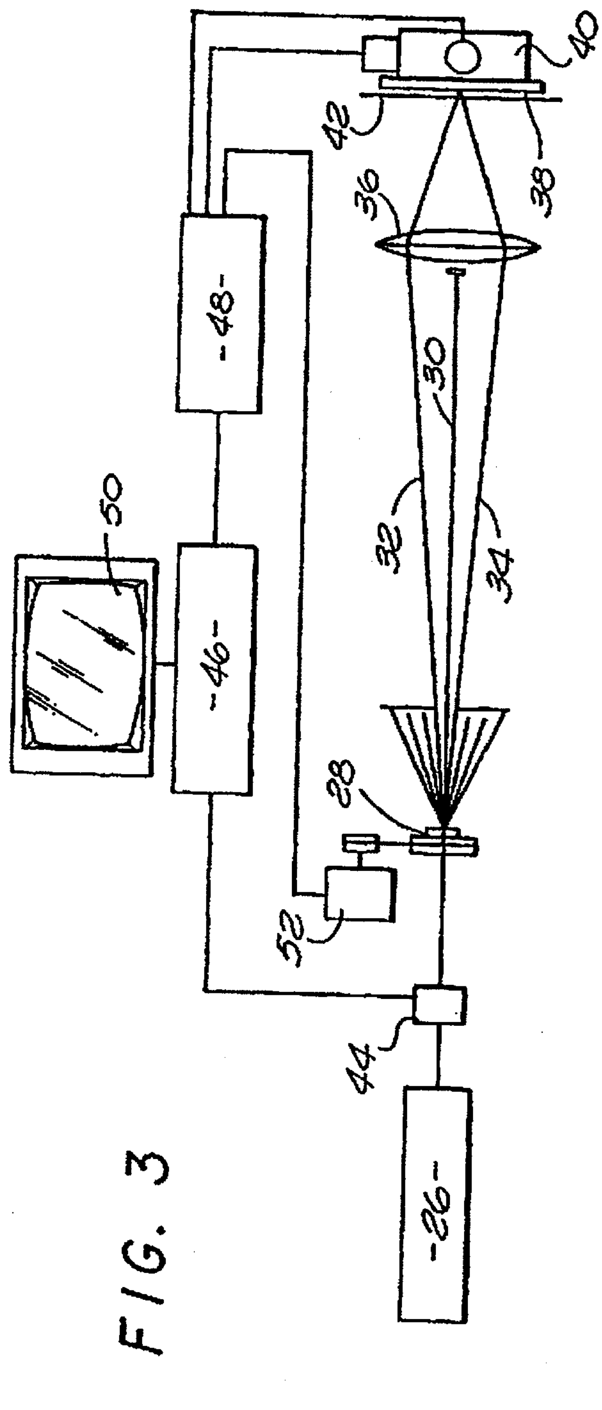

FIG. 3

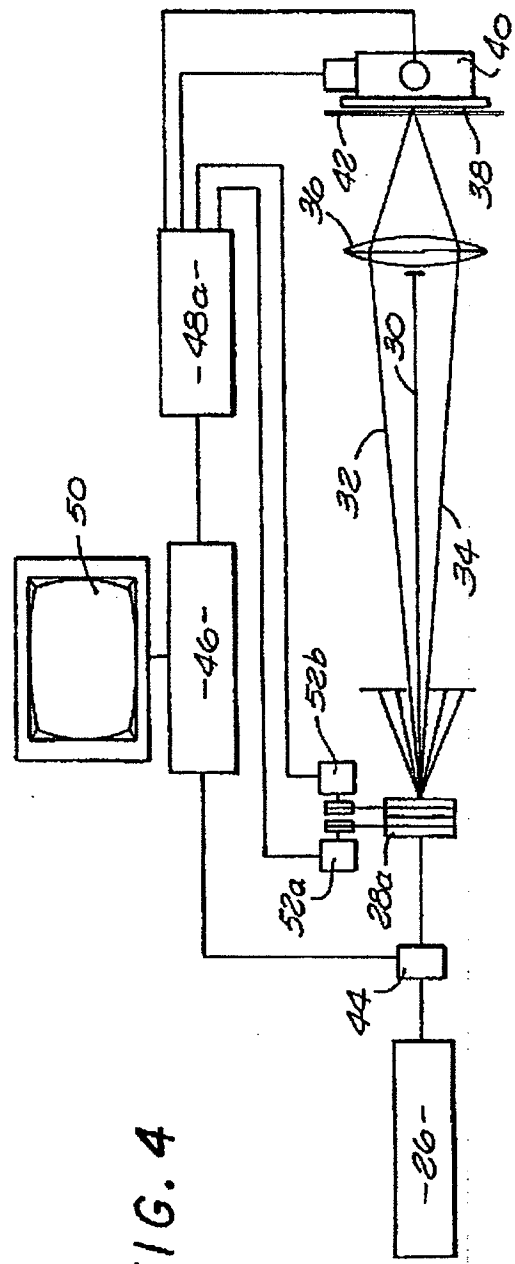
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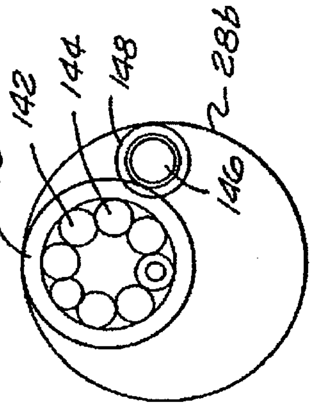
FIG. 4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148
28b
146

FIG. 5